STILL PIXEL DETECTION USING MULTIPLE WINDOWS AND THRESHOLDS

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BACKGROUND OF THE INVENTION

Field of the Invention

[0001]   The present invention relates to digital image and video processing. More specifically, the present invention relates to methods of noise reduction for interlaced digital video stream.

Discussion of Related Art

[0002]   Due to advancing semiconductor processing technology, integrated circuits (ICs) have greatly increased in functionality and complexity. With increasing processing and memory capabilities, many formerly analog tasks are being performed digitally. For example, images, audio and even full motion video can now be produced, distributed, and used in digital formats.

[0003]   Fig. 1 is an illustrative diagram of a portion of interlaced digital video stream 100 most often used in television systems. Interlaced digital video stream 100 comprises a series of individual fields 100_1 to 100_N, of which the first ten fields are shown. Even fields contain even numbered rows while odd fields contain odd numbered rows. For example if a frame has 400 rows of 640 pixels, the even field would contains rows 2, 4, … 400 and the odd field would contains rows 1, 3, 5, … 399 of the frame. In general for an interlaced video stream each field is formed at a different time. For example, an interlaced video capture device (e.g. a video camera) captures and stores the odd scan lines of a scene at time T as field 100_1, then the video capture device

stores the even scan lines of a scene at time T+1 as field 100_2. The process continues for each field.

[0004]   Figure 2 illustrates a conventional noise reduction system 200 having a digital buffer 210, a noise reduction unit 220, and a deinterlacer 230. Digital buffer 210 stores portions of an input interlaced video stream I_IVS. Typically, digital buffer 210 is configured to store an integer number of fields from input interlaced video stream I_IVS. In general, video streams are stored in YUV format, where Y is the luminance, and U and V are chrominance values. Noise reduction unit 220 reads image data from digital buffer 210 as appropriate for the noise reduction algorithm and generates an interlaced noise reduced digital video stream INRDVS which is provided to deinterlacer 230. Deinterlacer 230 processes corresponding fields to generate progressive video frames and output deinterlaced video stream O_DVS, which can be displayed on a progressive digital video device (not shown).

[0005]   Although digital images generally provide higher noise immunity, most digital images in digital video streams are converted from analog video streams. The original analog video stream may contain noise from various sources. For example, modulation, wireless transmission and demodulation of TV signals may introduce Gaussian-like noise. Furthermore, even analog video transferred over transmission lines may have Gaussian-like noise due to magnetic fields around the transmission lines. In addition, the digitalizing process may inadvertently amplify minor noise problems in the analog video stream.

[0006]   Hence, there is a need for a noise filtering method or system to reduce noise in a digital image. Furthermore, noise filtering in a digital video stream must be performed quickly to match the frame rate of the digital video stream.

SUMMARY

[0007]   Accordingly, the present invention provides a method and
system for determining whether pixels as still pixels and then
performing noise reduction on the still pixels. To provide
recursive noise reduction, some embodiments of the present
invention the noise reduction writes data back into the digital
buffer to perform recursive noise reduction. For example, a first
field having a plurality of pixels is stored in a first field
buffer. A second field is stored in a second field buffer. A
subset of pixels from the second field are modified using
information from the first field. The subset of pixels are stored
in the second buffer. A third field is stored in the first field
buffer. Then, a subset of pixels in the third field is modified
using information from the second field. The subset of modified
pixels is stored into the first buffer so that processing of a
later fourth frame can use the modified pixels.

[0008]   In some embodiments of the present invention, separate
noise reduction is performed on the luminance and chrominance
values of the pixels. For example processing a current pixel
includes determining whether the current pixel is a luminance
still pixel. If the current pixel is a luminance still pixel, the
luminance value of the current pixel is modified to reduce noise.
Furthermore, if the current pixel is a luminance still pixel, the
current pixel is tested to determine whether the current pixel is
a chrominance still pixel. If the current pixel is a chrominance
still pixel, the chrominance values of the current pixel are
modified to reduce noise.

[0009]   The present invention also incorporates novel still
pixel detection methods. In some embodiments of the present
invention, determining whether a current pixel is a still pixel
involves two windows defined around the current pixel.
Specifically, a first window is defined to include the current

pixel and other pixels. Generally the current first window includes the current pixel and a few pixels to the right of the current pixel. A second window is also defined. Generally, the second window includes the current pixel and a few pixels to the left of the current pixel. A first window still pixel test using the pixels in the first window and a second window still pixel test using the pixels in the second window are performed. If the current pixel passes either the first window still pixel test or the second window still pixel test, the current pixel is determined to be a still pixel.

[0010]   Some embodiments of the present invention use a multi-threshold test to determine whether a pixel in a defined window is a still pixel. Specifically, pixel pair differences are calculated for each pixel in the first window with a corresponding pixel in another field. If the absolute value of any pixel pair difference is greater than a difference threshold, the current pixel is determined to not be a still pixel. If the absolute values of the pixel pair differences are all less than the difference threshold, a correlation sum is generated by adding the absolute values of each pixel pair difference that is greater than a summation threshold. If the correlation sum divided by the size of the first window is less than or equal to a correlation threshold the current pixel is determined to be a still pixel. For embodiments of the present invention that use two windows the multi-threshold test can be used in both windows.

[0011]   The present invention will be more fully understood in view of the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]   Fig. 1 is an illustration of an interlaced digital video stream.

[0013]   Fig. 2 is a simplified block diagram of a conventional noise reduction system.

[0014]   Fig. 3 is a block diagram of a noise reduction system in accordance with one embodiment of the present invention.

[0015]   Fig. 4 is a flow diagram for noise reduction in accordance with one embodiment of the present invention.

[0016]   Fig. 5 is a flow diagram for still pixel detection in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION

[0017]   Because human vision is especially sensitive to high frequency noise in low frequency areas of a video stream, the present invention concentrates on reducing noise on still parts of the video stream. Thus, the present invention detects still pixels within the input interlaced video stream and provides noise reduction for the still pixels.

[0018]   Figure 3 is a simplified block diagram of a noise reduction system 300 having a digital buffer 310, a noise reduction unit 320 and a deinterlacer 330. In the embodiment of Figure 3, digital buffer 310 has three field buffers 310_1, 310_2, and 310_3. Digital buffer 310 is used as a circular buffer so that the first field of input interlaced video stream I_IVS is written into field buffer 310_1, the second fields of input interlaced video stream I_IVS is written into field buffer 310_2, the third field of input interlaced video stream I_IVS is written into field buffer 310_3. Then the fourth field of input interlaced video stream I_IVS is written into field buffer 310_1, the fifth fields of input interlaced video stream I_IVS is written into field buffer 310_2, and the sixth field of input interlaced video stream I_IVS is written into field buffer 310_3. This process continues for all the fields of input interlaced video stream I_IVS.

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[0019]   Thus, in general digital buffer 310 contains three
fields from input interlaced video stream I_IVS. Noise reduction
unit 320 generally uses an early field pointer EFP to track which
field buffer contains the earliest field and a late field pointer
LFP to track which field buffer contains the latest field. Thus
initially, early field pointer EFP would point to field buffer
310_1 and late field pointer LFP would point to field buffer
310_3. However as noise reduction unit 320 processes each field
early field pointer EFP and late field pointer LFP would be
incremented modulo 3 as explained in more detail below. For
convenience, the field in the buffer pointed to by early field
pointer EFP is called the "early field." Similarly, the field in
the buffer pointed to by late field pointer LFP is called the
"late field."

[0020]   Unlike conventional noise reduction systems which simply
perform averaging of multiple pixel data and do not re-use earlier
noise reduced results in later process, the embodiment of Figure 3
writes data back into digital buffer 310 to provide recursive
noise reduction. Moreover, some noise reduction parameters are
adaptively updated according to the evaluation of noise level.
Specifically, noise reduction unit 320 retrieves pixels in the
early field to process corresponding pixels in the late field and
perform noise reduction on the corresponding pixels of the late
field to form modified pixels as described in more detail below.
The modified pixels are used to form interlaced noise reduced
video stream INRDVS, which is provided to deinterlacer 330. In
addition, the modified pixels are written back into the late field
in digital buffer 310. Thus, for example, after modifying a field
X, the modified field X is used to modify a field X+2.

[0021]   Deinterlacer 330, combines corresponding fields into
full frames to generate output deinterlaced video stream O_DVS

which can be displayed on a progressive digital video device (not shown).

[0022]   Fig. 4 is a flow chart illustrating the function of noise reduction unit 320 (Fig. 3) in accordance with one embodiment of the present invention. The process illustrated by the flow chart of Figure 4 includes many user definable parameters which influences the amount and quality of noise reduction provided by noise reduction unit 320. These parameters include a minimum luminance threshold parameter Y_T_MIN, a minimum chrominance threshold parameter C_T_MIN, a luminance noise reduction level parameter Y_NRL, a chrominance noise reduction level parameter C_NRL, a luminance threshold update parameter Y_TU, and a chrominance threshold update parameter C_TU. Furthermore, the process illustrated by the flow chart of Figure 4 also includes many process parameters such as a luminance threshold parameter Y_T, a chrominance threshold parameter C_T, a luminance still pixel count parameter Y_CNT, a chrominance still pixel count parameter C_CNT, a luminance difference summation parameter Y_SUMM, a chrominance difference summation parameter C_SUMM, a luminance motion parameter Y_M, a U chrominance motion parameter U_M, and a V chrominance motion parameter V_M.

[0023]   Luminance threshold parameter Y_T and chrominance threshold parameter C_T are used to determine if pixels are still, i.e. not moving, based on luminance and chrominance, respectively. Because, luminance threshold parameter Y_T and chrominance threshold parameter C_T are adaptively updated, the user defined parameters minimum luminance threshold parameter Y_T_MIN and minimum chrominance parameter C_T_MIN define lower bounds for luminance threshold parameter Y_T and chrominance threshold parameter C_T, respectively. Luminance threshold update parameter Y_TU and chrominance threshold update parameter C_TU are used to control the rate that luminance threshold parameter Y_T and

chrominance threshold parameter C_T are respectively updated as
explained below. Luminance noise reduction level parameter Y_NRL
controls the level of noise reduction based on luminance.
Luminance noise reduction level parameter Y_NRL ranges from 0 to
1, inclusive. A lower value for luminance noise reduction level
parameter Y_NRL provides higher level of noise reduction but may
cause obvious shadows for moving objects. Conversely, higher
value of luminance noise reduction level parameter Y_NRL provides
less noise reduction. A value of 1 would actually "turn off"
noise reduction. Generally, values of 0.25 to 0.75 provide
acceptable results. Chrominance noise reduction level parameter
C_NRL is the corresponding parameter for both chrominance
parameters U and V. Luminance motion parameter Y_M gives an
indication of the movement in terms of luminance of a pixel
between the early field and the late field. Similarly, U
chrominance motion parameter U_M and V chrominance motion
parameter V_M, give an indication of the movement in terms of
chrominance values of a pixel between the early field and the late
field.

[0024]   Table 1 provides the ranges and default values for the
various user defined parameters for a specific embodiment of the
present invention.

TABLE 1

PARAMETER	RANGE	DEFAULT VALUE
Y_T_MIN	[0, 255]	10
C_T_MIN	[0, 255]	30
Y_TU	[1, 3]	2
C_TU	[1, 3]	3
Y_NRL	[0, 1]	0.5
C_NRL	[0, 1]	0.5

[0025]   The method illustrated by the flow chart of Figure 4
begins by initializing luminance threshold parameter Y_T and

chrominance threshold parameter C_T to be equal to minimum luminance threshold parameter Y_T_MIN and minimum chrominance parameter C_T_MIN, respectively in initialize threshold parameters step 405.

[0026]   Noise reduction unit 320 then begins to process the fields in digital buffer 310. Each pixel in the late field is processed sequentially. For clarity, the method is described below using the term "late current pixel" to represent the pixel being processed in the late field and the term "early current pixel" to represent the corresponding pixel in the early field having the same relative location as the late current pixel. Each pixel in the late field will be the late current pixel at some point. At the start of each field the field parameters are reset in reset field parameters step 410. Specifically, luminance still pixel count parameter Y_CNT and chrominance still pixel count parameter C_CNT are set equal to 1. The value 1 is chosen instead of zero to avoid possible division by zero errors that may occur in the case of completely different fields in terms of luminance and/or chrominance, i.e. every "late current pixel" in the late field is determined as non-still pixel in terms of luminance and/or chrominance. Luminance difference summation parameter Y_SUMM and chrominance difference summation parameter C_SUMM are set equal to 0.

[0027]   In determine luminance motion step 415, noise reduction unit 320 calculates the luminance motion parameter Y_M, which is equal to the luminance value of the late current pixel in the late field minus the luminance value of the early current pixel in the early field. Furthermore, noise reduction unit 320 determines whether the late current pixel is a "luminance still pixel." In one embodiment of the present invention the late current pixel is classified as a "luminance still pixel" if the absolute value of luminance motion parameter Y_M is less than luminance threshold

parameter Y_T. Another method to determine whether the late
current pixel is a luminance still pixel is described below with
respect to Fig. 5. If the late current pixel is not a luminance
still pixel and the late current pixel is not the last pixel in
the field, then the next pixel in the field is selected as the
late current pixel and noise reduction unit 320 performs determine
luminance motion step 415 again. If the late current pixel is not
a luminance still pixel and the late current pixel is the last
pixel in the field, processing proceeds to update threshold
parameters step 445 (described below). If the late current pixel
is a luminance still pixel then processing proceeds to calculate
new luminance value step 420.

[0028]   In calculate new luminance value step 420, the luminance
value of the late current pixel is recomputed to be equal to the
luminance value of the early current pixel plus luminance noise
reduction level parameter Y_NRL multiplied by luminance motion
parameter Y_M. Then, the luminance field parameters are updated
in update luminance field parameters step 425. Specifically,
luminance still pixel count parameter Y_CNT is incremented by one
and a luminance difference summation parameter Y_SUMM is
incremented by luminance motion parameter Y_M squared.

[0029]   In determine chrominance motion step 430, noise
reduction unit 320 calculates U chrominance motion parameter U_M,
which is equal to the U chrominance value of the late current
pixel in the late field minus the U chrominance value of the early
current pixel in the early field. In addition, noise reduction
unit 320 calculates V chrominance motion parameter V_M, which is
equal to the V chrominance value of the late current pixel in the
late field minus the V chrominance value of the early current
pixel in the early field. Furthermore, noise reduction unit 320
determines whether the late current pixel is a "chrominance still
pixel." In one embodiment of the present invention the late

current pixel is classified as a "chrominance still pixel" if the absolute value of U chrominance motion parameter U_M is less than chrominance threshold parameter C_T and the absolute value of V chrominance motion parameter V_M is less than chrominance threshold parameter C_T. The method to determine whether the late current pixel is a luminance still pixel as described below with respect to Fig. 5 can also be used to determine whether the late current pixel is a chrominance still pixel. If the late current pixel is not a chrominance still pixel and the late current pixel is not the last pixel in the field, then the next pixel in the field is selected as the late current pixel and noise reduction unit 320 performs determine luminance motion step 415 again. If the late current pixel is not a chrominance still pixel and the late current pixel is the last pixel in the field, processing proceeds to update threshold parameters step 445 (described below). If the late current pixel is a chrominance still pixel then processing proceeds to calculate new chrominance value step 435.

[0030]   In calculate new chrominance values step 435, the U chrominance value of the late current pixel is recomputed to be equal to the U chrominance value of the early current pixel plus chrominance noise reduction level parameter C_NRL multiplied by U chrominance motion parameter U_M. Similarly, the V chrominance value of the late current pixel is recomputed to be equal to the V chrominance value of the early current pixel plus chrominance noise reduction level parameter C_NRL multiplied by V chrominance motion parameter V_M. Then, the chrominance field parameters are updated in update chrominance field parameters step 440. Specifically, chrominance still pixel count parameter C_CNT is incremented by two and a chrominance difference summation parameter C_SUMM is incremented by U chrominance motion parameter U_M squared and V chrominance motion parameter V_M squared.

[0031]   Then, noise reduction unit 320 adaptively updates the threshold values in update threshold parameters step 445. Specifically, luminance threshold parameter Y_T is set equal to the greater of minimum luminance threshold parameter Y_T_MIN or luminance threshold update parameter Y_TU multiplied by the square root of half of luminance difference summation parameter Y_SUMM divided by luminance pixel count parameter Y_CNT, i.e., Y_T=max(Y_T_MIN, (Y_TU*sqrt(0.5*Y_SUMM/Y_CNT))). Similarly, chrominance threshold parameter C_T is set equal to the greater of minimum chrominance threshold parameter C_T_MIN or chrominance threshold update parameter C_TU multiplied by the square root of half of chrominance difference summation parameter C_SUMM divided by chrominance pixel count parameter C_CNT, i.e., C_T=max(C_T_MIN, (C_TU*sqrt(0.5*C_SUMM/C_CNT))). If the late current pixel is not the last pixel in the field, then the next pixel in the field is selected as the late current pixel and noise reduction unit 320 performs determine luminance motion step 415 again. Otherwise, the field pointers are incremented in increment field pointers step 450. Specifically, if early field pointer EFP is pointing to field buffer 310_X, early field pointer EFP is set to point to field buffer 310_((X+1) MOD 3). Similarly, if late field pointer LFP is pointing to field buffer 310_Y, late field pointer LFP is set to point to field buffer 310_((Y+1) MOD 3). Processing of the next field begins in reset field parameters step 410.

[0032]   Fig. 5 is a flow diagram for determining whether the late current pixel is a luminance still pixel. In general, the method of Fig. 5 tests the late current pixel using both a right window still pixel test and a left window still pixel test (described in detail below). If the late current pixel passes the either the right window still pixel test or the left window still pixel test as described below, then the late current pixel is considered a "luminance still pixel". In the embodiment of Figure

5, an optional low pass filter can be applied in apply low pass filter step 505. Generally, the low pass filter can be enabled or disabled by a user. Furthermore, the user can determine the order of the low pass filter. For example, in one embodiment of the present invention, a fifth order low pass filter is used with a cut frequency between 4.5 Mhz and 6 Mhz, inclusive. In general, pixels modified by the low pass filter are only used during still pixel detection. The unmodified values are used to calculate values for luminance and chrominance during noise reduction. If the low pass filter is enabled, the low pass filter can be applied to the entire row or to each window independently.

[0033]   A late right filter window for the late current pixel and an early right filter window for the early current pixel are defined in define right filter windows 510. The late right filter window of size N for the late current pixel would include the late current pixel and the next N-1 pixels to the right of the late current pixel in the late field. Similarly, the early right filter window for the early current pixel would include the early current pixel and the next N-1 pixels to the right of the early current pixel in the early field. Then, for each pixel in the late right filter window, the absolute value of the difference between the luminance of the pixel in the late right filter window and the luminance of the corresponding pixel in the early right filter window is calculated in calculate pixel pair absolute differences step 515. In difference threshold step 520, the absolute value of the difference of luminance values for each pair of pixels is compared to a difference threshold DT, which is user configurable. If the absolute value of the difference of luminance value for any pair is greater than difference threshold then the late current pixel is not considered a luminance still pixel using the right window test; therefore, processing is passed to define left filter window step 535 to perform the left window

tests. However, if every absolute value of the differences in luminance value for each pair of pixels is less than or equal to difference threshold DT, then processing continues in difference summation step 525. In one embodiment of the present invention, difference threshold DT has a default value of 40 in a range from 0 to 255 inclusive. In some embodiments of the present invention difference threshold step 520 is omitted. Alternatively, difference threshold DT can be set to a maximum value (such as 255) to disable difference threshold step 520.

[0034]   In difference summation step 525, a correlation sum C_SUM, which is initialized at zero, is generated from the absolute values of differences of luminance value for each pixel. Specifically, for each pair of pixels, the absolute value of the difference in luminance values is compared to a summation threshold ST. If the absolute value of the difference is greater than summation threshold ST, the absolute value of the difference in luminance value is added to correlation sum C_SUM. Otherwise, correlation sum C_SUM is not increased. Some embodiments of the present invention do not use summation threshold ST. In these embodiments, the absolute value of differences for every pixel in the right window is added to correlation sum C_SUM. Alternatively, summation threshold ST could be set to be zero to achieve the same effect.

[0035]   Then, correlation sum C_SUM is divided by the size of the late right window and compared to a correlation threshold CT in correlation threshold step 530. If correlation sum C_SUM divided by the size of the late right window is less than or equal to correlation threshold CT, then the late current pixel is classified as a luminance still pixel. Otherwise the late current pixel must be further processed beginning in define left windows step 535. When the method of Fig. 5 is used with noise reduction unit 320 in the method of Fig. 4, correlation threshold CT is

equivalent to luminance threshold parameter Y_T for luminance still pixel detection. As described above, luminance threshold parameter Y_T is adaptively adjusted during noise reduction. Thus, correlation threshold CT is also adaptively adjusted when used by noise reduction unit 320.

[0036]   If the late current pixel is classified as a luminance still pixel in correlation threshold step 530 and the late current pixel is the last pixel of a line then processing is passed to apply low pass filter step 505 and the next pixel (i.e. the first pixel of the next line) becomes the late current pixel. If the late current pixel is classified as a luminance still pixel in correlation threshold step 530 and the late current pixel is not the last pixel of a line then processing is passed to define right windows step 510 and the next pixel becomes the late current pixel. In one embodiment of the present invention, summation threshold ST and correlation threshold CT are user configurable in the range of 0 to 255 inclusive, but have default values of 5 and 15, respectively.

[0037]   In define left windows step 535, a late left filter window for the late current pixel and an early left filter window for the early current pixel are defined. The late left filter window of size N for the late current pixel would include the late current pixel and the next N-1 pixels to the left of the late current pixel in the late field. Similarly, the early left filter window of size N for the early current pixel would include the early current pixel and the next N-1 pixels to the left of the early current pixel in the early field. Then, for each pixel in the late left filter window, the absolute value of the difference between the luminance of the pixel in the late left pixel window and the luminance of the corresponding pixel in the early left pixel window is calculated in calculate pixel pair absolute differences step 540. In difference threshold step 545, the

absolute value of the difference of luminance values for each pair of pixels is compared to a difference threshold DT, which is user configurable. If the absolute value of the difference of luminance value for any pair is greater than difference threshold then the late current pixel is not considered a luminance still pixel using the left window test. In some embodiments of the present invention difference threshold step 545 is omitted. Alternatively, difference threshold DT can be set to a maximum value (such as 255) to disable difference threshold step 545.

[0038] Because the late current pixel has already failed the right window tests, the late current pixel is classified as a luminance non-still pixel. Processing on the next pixel is then passed to apply low pass filter step 505 if the late current pixel was the last pixel of a row. Otherwise processing on the next pixel is passed to define right windows step 510. However, if every absolute value of the differences in luminance value for each pair of pixels is less than or equal to difference threshold DT, then processing continues in difference summation step 555.

[0039] In difference summation step 555, a correlation sum C_SUM, which is initialized at zero, is generated from the absolute values of differences of luminance value for each pixel. Specifically, for each pair of pixels, the absolute value of the difference in luminance values is compared to a summation threshold ST. If the absolute value of the difference is greater than summation threshold ST, the absolute value of the difference in luminance value is added to correlation sum C_SUM. Otherwise, correlation sum C_SUM is not increased. Some embodiments of the present invention do not use summation threshold ST. In these embodiments, the absolute value of differences for every pixel in the left window is added to correlation sum C_SUM. Alternatively, summation threshold ST could be set to be zero to achieve the same effect.

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[0040] Correlation sum C_SUM is divided by the size of the late left window and compared to a correlation threshold CT in correlation threshold step 560. If correlation sum C_SUM divided by the size of the late left window is less then or equal to correlation threshold CT, then the late current pixel is classified as a luminance still pixel. Otherwise the late current pixel is classified as a luminance non-still pixel. If the late current pixel is the last pixel of a line then processing is passed to apply low pass filter step 505 and the next pixel (i.e. the first pixel of the next line) becomes the late current pixel. If the late current pixel is not the last pixel of a line then processing is passed to define right windows step 510 and the next pixel becomes the late current pixel. If the late current pixel is the last pixel of the field then processing can begin again with the first pixel of a next set of fields. In one embodiment of the present invention, summation threshold ST and correlation threshold CT are user configurable in the range of 0 to 255 inclusive, but have default values of 5 and 15, respectively.

[0041] Although, Figure 5 is described with respect to luminance values to determine luminance still pixels. The method illustrated by Fig. 5 can also be applied to determine whether the late current pixel is a chrominance still pixel. Specifically, classification of chrominance still pixels can be determined by simply using chrominance values in place of luminance values. In one embodiment of the present invention, when the method illustrated in Fig. 5 is used for chrominance still pixel detection, default values for summation threshold ST and difference threshold DT are 10 and 70, respectively. When the method of Fig. 5 is used with noise reduction unit 320 in the method of Fig. 4 for chrominance still pixel detection, correlation threshold CT is equivalent to chrominance threshold parameter C_T for chrominance still pixel detection. As described

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above, chrominance threshold parameter C_T is adaptively adjusted during noise reduction. Thus, correlation threshold CT is also adaptively adjusted when used by noise reduction unit 320. However, in some embodiments of the present invention, both the U chrominance and the V chrominance values must meet the still pixel criterions.

[0042]   In the various embodiments of the present invention, novel structures have been described for noise filtering systems. By using a recursive scheme with a novel method for classifying still pixels higher picture quality can be achieved. The various embodiments of the structures and methods of this invention that are described above are illustrative only of the principles of this invention and are not intended to limit the scope of the invention to the particular embodiments described. For example, in view of this disclosure those skilled in the art can define other still pixel tests, pixel pair differences, windows, thresholds, and so forth, and use these alternative features to create a method, circuit, or system according to the principles of this invention. Thus, the invention is limited only by the following claims.